

Application No. 09/881,684
Amendment filed January 30, 2004
Reply to Final Office Action dated September 30, 2003

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Amendments to the Claims:

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

Claim 1 (currently amended): A method of manufacturing a material comprising:

(a) producing raw nanostructure or nanotube-containing material comprising closed structures;

(b) purifying the raw material;

(c) processing the purified material thereby forming openings in the closed structures;

(d) introducing a foreign species comprising electron donors or electron acceptors into at least some of the openings;

(e) varying at least one of electronic work function, electronic density of state at the Fermi Level, and electrical conductivity of the material by controlling the amount of foreign species introduced at step (d); and

(f) closing the openings by forming passivation layers, the passivation layers being formed by exposing the nanostructure or nanotube-containing material containing the foreign species to oxygen or an oxygen-containing gas, thereby forming capsules filled with the foreign species.

Claim 2 (original): The method of claim 1, wherein step (a) comprises producing single-walled carbon nanotube-containing material.

Claim 3 (original): The method of claim 1, wherein step (a) comprises producing multi-walled carbon nanotube-containing material.

Claim 4 (original): The method of claim 1, wherein step (a) comprises directionally growing carbon nanotubes on a support surface.

Claim 5 (original): The method of claim 1, wherein step (a) comprises producing carbon nanoparticles with concentric fullerene-type structures.

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Claim 6 (original): The method of claim 1, wherein step (a) comprises producing nanotube structures with composition of $B_xC_yN_z$, where B = boron, C = carbon, and N = nitrogen.

Claim 7 (original): The method of claim 1, wherein step (a) comprises producing nanotube structures with composition of MS_2 , where M = tungsten, molybdenum or vanadium oxide.

Claim 8 (original): The method of claim 1, wherein step (a) comprises producing concentric fullerene structures with composition of MS_2 , where M = tungsten, molybdenum or vanadium oxide.

Claim 9 (original): The method of claim 1, wherein step (b) comprises subjecting the raw material to ultrasonic filtration.

Claim 10 (original): The method of claim 1, wherein step (b) comprises subjecting the raw material to a reflux procedure in an acidic medium.

Claim 11 (original): The method of claim 1, wherein step (b) comprises subjecting the raw material first to a reflux procedure in an acidic medium, then to filtration.

Claims 12 and 13 (canceled).

Claim 14 (original): The method of claim 1, wherein step (b) comprises subjecting the raw material to oxidation in air or oxygen environment at a temperature of 300-600°C.

Claim 15 (original): The method of claim 1, wherein step (c) comprises ultrasonication of the purified material in an acidic medium.

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Claim 16 (original): The method of claim 1, wherein step (c) comprises milling the purified material.

Claim 17 (original): The method of claim 1, wherein step (c) comprises bombarding the purified material with ions, then subjecting the material to ultrasonication in an acidic medium.

Claim 18 (original): The method of claim 1, wherein step (c) comprises subjecting the purified material to plasma etching.

Claim 19 (original): The method of claim 18, wherein the plasma etching comprises etching with hydrogen or oxygen plasma.

Claim 20 (original): The method of claim 1, wherein the foreign species of step (d) comprises at least one alkali metal or an alloy of an alkali metal.

Claim 21 (canceled).

Claim 22 (original): The method of claim 1, wherein the foreign species of step (d) comprises at least one of Mg, Ca, Sr, Ba, or an alloy thereof.

Claim 23 (original): The method of claim 1, wherein the foreign species of step (d) comprises at least one of Sc, Y, Fe, Co, Ni, Cu, or an alloy thereof.

Claim 24 (original): The method of claim 1, wherein the foreign species of step (d) comprises at least one of a Lewis acid, halogen mixture, metal chloride, metal bromide, metal fluoride, metal oxyhalide, an acidic oxide, and a strong acid.

Claim 25 (canceled).

Claim 26 (original): The method of claim 1, wherein the foreign species of step (d) comprises cesium.

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Claim 27 (original): The method of claim 1, wherein step (d) comprises vapor phase transportation of the foreign species.

Claim 28 (original): The method of claim 1, wherein step (d) comprises evaporation of the foreign species from a source.

Claim 29 (original): The method of claim 1, wherein step (d) comprises solid state reaction of chemicals containing the foreign species and the processed purified material.

Claim 30 (original): The method of claim 1, wherein step (d) comprises electrochemical reaction between the foreign species and the processed purified material.

Claim 31 (canceled).

Claim 32 (previously presented): The method of claim 1, wherein the passivation layers are formed by dispersing the filled capsules in a solvent.

Claim 33 (canceled).

Claim 34 (original): The method of claim 1, further comprising:
(f) removing reaction products from the outer surfaces of the filled capsules.

Claim 35 (original): The method of claim 1, further comprising:
(f) forming a field-emitting cathode by screen printing, electrophoretic deposition, spin coating, casting, spraying or sputtering of the capsules.

Claim 36 (previously presented): The method of claim 1, wherein the foreign species comprises at least one of: Li, Na, K, Rb, Cs, Mg, Ca, Sr, Ba, Sc, Y, Fe, Co, Ni, Cu, or alloys thereof; a Lewis acid; halogen mixtures; metal chlorides; metal bromides; metal fluorides; metal oxyhalides; acidic oxides; and at least one of HNO_3 and H_2SO_4 .

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Claim 37 (previously presented) The method of claim 36, wherein the foreign species comprises at least one of: Li, Na, K, Rb, Cs, Mg, Ca, Sr, Ba, Sc, Y, Fe, Co, Ni, Cu, or alloys thereof; a Lewis acid; halogen mixtures; metal chlorides; metal bromides; metal fluorides; metal oxyhalides; acidic oxides; and at least one of HNO_3 and H_2SO_4 .

Claim 38 (previously presented): The method of claim 36, wherein the Lewis acid comprises halogen Br_2 , and the acidic oxide comprises N_2O_5 or SO_3 .

Claim 39 (original): The method of claim 1, wherein the materials produced after step (d) have an electronic workfunction of less than 5.5 eV.

Claim 40 (original): The method of claim 1, wherein the materials produced after step (d) have an electronic workfunction of less than 4 eV.

Claim 41 (original): The method of claim 1, wherein the materials produced after step (d) have an electronic workfunction of less than 3 eV.

Claim 42 (canceled).

Claim 43 (original): The method of claim 1, wherein the materials produced after step (e) have an electronic workfunction of less than 4 eV.

Claim 44 (original): The method of claim 1, wherein the materials produced after step (e) have an electronic workfunction of less than 3 eV.

Claim 45 (original): The method of claim 1, further comprising varying the electronic workfunction of the materials produced after step (d) by 0 to 3 eV by controlling the amount of foreign species intercalated.

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Claim 46 (original): The method of claim 1, further comprising varying the electronic workfunction of the materials produced after step (e) by 0 to 3 eV by controlling the amount of foreign species intercalated.

Claim 47 (original): The method of claim 1, wherein the materials produced after step (d) have a metallic behavior.

Claim 48 (original): The method of claim 1, wherein the materials produced after step (e) have a metallic behavior.

Claims 49-52 (canceled).

Claim 53 (previously presented): A method of manufacture comprising:
(a) producing vertically oriented carbon nanotubes on a support surface;
(b) applying an insulating layer;
(c) opening tops of the nanotubes;
(d) introducing a foreign species into the open tops and into interior spaces of the nanotubes;
(e) closing the open tops of the nanotubes by forming passivation layers; and
(f) activating the filled nanotubes.

Claim 54 (original): The method of claim 53, wherein step (a) comprises producing the nanotubes by chemical vapor deposition.

Claim 55 (original): The method of claim 53, wherein the insulating layer in step (b) comprises a polymer.

Claim 56 (original): The method of claim 53, wherein step (c) comprises etching.

Claim 57 (original): The method of claim 56, wherein step (c) comprises chemical etching, hydrogen plasma etching or oxygen plasma etching.

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Claim 58 (original): The method of claim 57, wherein step (c) includes removal of at least a portion of the insulating layer.

Claim 59 (original): The method of claim 53, wherein step (d) comprises evaporation of the foreign species.

Claim 60 (original): The method of claim 53, wherein step (d) comprises electrochemical reaction of the foreign species.

Claim 61 (previously presented): The method of claim 53, wherein step (e) comprises forming the passivation layers, thereby closing the open ends.

Claim 62 (original): The method of claim 53, wherein step (f) comprises exposing the filled nanotubes to hydrogen plasma.

Claims 63-72 (canceled).

Claim 73 (new): The method of claim 1, wherein the material has an electron emission turn-on field of less than $2 \text{ V}/\mu\text{m}$ to obtain an electron emission current density of $0.01 \text{ mA}/\text{cm}^2$.

Claim 74 (new): The method of claim 73, wherein the material has an electron emission turn-on field of less than $1 \text{ V}/\mu\text{m}$.

Claim 75 (new): The method of claim 73, wherein the material has an electron emission turn-on field of less than $0.5 \text{ V}/\mu\text{m}$.